TWEM: An Integral Model for Estimating Risks to Wildlife Within ARAMS

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abstract

The Army Risk Assessment Modeling System (ARAMS) is being developed to facilitate and standardize human and ecological risk assessments. Assessment of wildlife risks, a key component of ARAMS, requires exposure modeling. The Terrestrial Wildlife Exposure Model (TWEM) was developed and parameterized for incorporation into ARAMS. TWEM generates estimates of total oral exposure based on ingestion of food, soil, and surface water. Dermal and inhalation exposures are not currently incorporated, but may be in the future. TWEM incorporates exposure data for 26 birds, 21 mammals, and 8 reptiles derived from reports from the U.S. EPA and Oak Ridge National Laboratory. Exposure data for an additional six bird and four mammal species that may occur on Army installations have also been developed. All receptors have been categorized to ecological guilds to allow greater utility of the model. Exposure estimation also requires chemical-specific bioaccumulation models. Existing bioaccumulation models for different wildlife food types have been identified and incorporated. Where bioaccumulation models are lacking, data extracted from published literature were used to develop new models. Exposure estimates from TWEM will be integrated within ARAMS to a Terrestrial Toxicity Database developed for the Army to generate estimates of risk. TWEM will allow users to select receptors based on habitat availability at a given contaminated site and species-specific habitat requirements. This model will generate both a conservative screening and a more refined exposure estimate by allowing the user to choose other relevant parameters (e.g., Area Use Factors, site-specific BAFs, regional specific body weights, etc.).

introduction

what is ARAMS?

The Army Risk Assessment Modeling System (ARAMS) is a computer-based, knowledge delivery, and decision support system that integrates multimedia fate/transport, exposure, intake/uptake, and effects of contaminants and military relevant compounds to assess human and ecological health impacts/risks for existing and future conditions.

what is TWEM?

The Terrestrial Wildlife Exposure Model (TWEM) is an easy to use ARAMS frame that produces biota concentrations and oral exposure estimates based on abiotic and biotic media concentrations and receptor-specific life history parameters (Figure 1). Since the user controls all parameters in the calculation engine, the reported values are customized to the desired level of specificity and conservatism.

TWEM progress, timeline, and future steps

- FRAMES (Framework for Risk Analysis in Multimedia Environmental Systems) integration—November, 2002
- Allow FRAMES to view TWEM1 model exposure data via Exposure Viewer—November, 2002
- Ability to select bioaccumulation model type and input values for model—November, 2002
- Protect system/project/master data from additions, deletions, and edits—Implemented with password protection; Advanced security (user accounts and access rights levels)—Proposed
- Ability to select FIR and WIR values—Implemented; Ability to select BW, Ps, and diet values - Implemented for default and custom only (selection of alternatives proposed)
- Ability to save references for user-entered input values—November, 2002
- Detailed and summary exposure reports and receptor-related input value reports—November, 2002
- Comprehensive manual for users of application with all features and functionality explained and detailed with images—Working document in progress
- Ability to enter input value data into system database via data entry tool - Proposed
- Ability to import input value data into TWEM1 via data import tool (currently, only chemical concentrations can be imported)—Proposed
- Ability to reduce time-series and spatially-distributed input data into single-point values for TWEM1 calculations with possibility of outputting spatially-distributed or time-series data—Proposed

acknowledgements

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Table 1
Summary of Species Presented in the *Wildlife Exposure Factors Handbook* (EPA, 1993)

Birds	Mammals	Reptiles or Amphibians
Great Blue Heron	Short-tailed Shrew	Snapping Turtle
Canada Goose	Red Fox	Painted Turtle
Mallard Duck	Raccoon	Eastern Box Turtle
Lesser Scaup	Mink	Racer
Osprey	River Otter	Northern Water Snake
Red-Tailed Hawk	Harbor Seal	Eastern Newt
Bald Eagle	Deer Mouse	Green Frog
American Kestrel	Prairie Vole	Bullfrog
Northern Bobwhite Quail	Meadow Vole	
American Woodcock	Muskrat	
Spotted Sandpiper	Eastern Cottontail Rabbit	
Herring Gull		
Belted Kingfisher		
Marsh Wren		
American Robin		

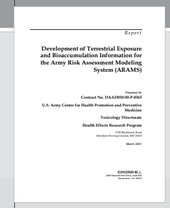
TWEM incorporates life history exposure data for 26 birds, 21 mammals, and 8 reptiles derived from reports from the U.S. EPA and Oak Ridge National Laboratory (Tables 1 and 2). Data for an additional six bird and four mammal species that may occur on Army installations have also been developed (Table 3).

Table 2
Summary of Species Presented in *Methods and Tools for Estimation of the Exposure of Terrestrial Wildlife to Contaminants* (Sample et al., 1997a)

Birds	Mammals
Green Heron	Little Brown Bat
Burrowing Owl	Green Basin Pocket Mouse
Cooper's Hawk	Pine Vole
Western Meadowlark	Black-tailed Jackrabbit
Swallows (tree,violet-green, bank, northern rough-winged, purple martin, cliff and cave)	Mule Deer
	Coyote
	Kit Fox
	Weasels (long-tailed, short-tailed and least)

Table 3
New U.S. Army Relevant Receptor Species

Birds	Mammals
Black-crowned Nightheron	Desert Shrew
Wild Turkey	Big Brown Bat
Mourning Dove	Pocket Gopher spp.
Roadrunner	Northern Grasshopper Mouse
Northern Flicker	
Red-winged Blackbird	



To estimate the magnitude of contaminant exposure that wildlife may experience, contaminant concentrations in food items preferred by endpoint species were developed.

Analytes evaluated were those relevant to U.S. Army installations and include metals/inorganics, explosives, chlorinated organics, polycyclic aromatic hydrocarbons (PAHs), and uranium (Table 4).

Table 4
List of U.S. Army Relevant Analytes for Which There Are Either Existing or New Empirically-Derived Bioaccumulation Data

Analytes	Existing Data	New Data
Explosives		
Cyclotrimethylenetrinitramine (RDX)		Root Leaf
2,4,6-Trinitrotoluene (TNT)		Root Leaf
2-Amino 4,5-dinitrotoluene (2-ADNT)		Root Leaf
4-Amino 2,6-dinitrotoluene (4-ADNT)		Root Leaf
Inorganics		
Arsenic	Plants Earthworms Small Mammals Benthic Invertebrates Aquatic Organisms	Root Leaf Fruit Seed Whole Plant Terrestrial Invertebrates
Cadmium	Plants Earthworms Small Mammals Benthic Invertebrates Aquatic Organisms	Root Leaf Terrestrial Invertebrates
Cobalt	Plants Earthworms Small Mammals	Leaf Seed Terrestrial Invertebrates
Copper	Plants Earthworms Small Mammals Benthic Invertebrates Aquatic Organisms	Root Leaf Stem Fruit Seed Whole Plant Terrestrial Invertebrates
Lead	Plants Earthworms Small Mammals Benthic Invertebrates Aquatic Organisms	Leaf Fruit Seed Whole Plant Terrestrial Invertebrates
Mercury (elemental)	Plants Earthworms Small Mammals Benthic Invertebrates	Leaf Seed Terrestrial Invertebrates
Mercury (methyl)	Aquatic Organisms	
Selenium	Plants Earthworms Small Mammals Aquatic Organisms	Root Leaf Stem Fruit Seed Terrestrial Invertebrates
Uranium	Earthworms	Root Leaf Stem Fruit Seed
Vanadium	Earthworms Small Mammals	Root Leaf Seed Terrestrial Invertebrates
Zinc	Plants Earthworms Small Mammals Benthic Invertebrates Aquatic Organisms	Root Leaf Fruit Seed Whole Plant Terrestrial Invertebrates
Organics		
DDT, DDD, DDE	Plants Small Mammals	
Dieldrin	Plants Earthworms Small Mammals	
PCBs (total)	Earthworms Benthic Invertebrates	
PAHs	Plants	Root Leaf

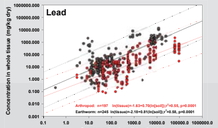


Figure 2. Literature-derived lead bioaccumulation regression model for all soil invertebrates.

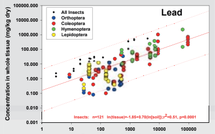


Figure 3. Literature-derived lead bioaccumulation regression model for soil invertebrate classes.

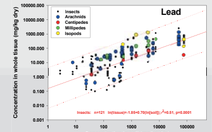


Figure 4. Literature-derived lead bioaccumulation regression model for arthropods.

TWEM function

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- h a ato s th o trat o data th bioaccumulation models from a chemical-specific database to produce estimated chemical concentrations in different biota types.
- The calculation engine incorporates measured or estimated abiotic and biotic media concentration data into the wildlife exposure model (below) to generate chemical exposure estimates (doses).

The wildlife exposure model is:

$$E_j = [Soil_j \times P_s] \times FIR \times \left[\sum_{i=1}^{n} P_i \times B_i\right] + [Water_j \times WIR]$$

where,

E_j = total exposure to chemical (j) (mg/kg/d)
$Soil_j$ = concentration of chemical (j) in soil (mg/kg)
P_s = soil ingestion rate as proportion of diet
FIR = species-specific food ingestion rate (kg food/kg body weight/d)
B_i = concentration of chemical (j) in biota type (i) (mg/kg)
P_i = proportion of biota type (i) in diet
$Water_j$ = concentration of chemical (j) in water (mg/L)
WIR = species-specific water ingestion rate (L/kg body weight/d)

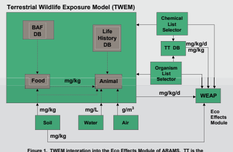


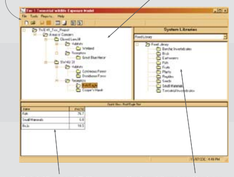
Figure 1. TWEM integration into the Eco Effects Module of ARAMS. TF is the Terrestrial Toxicity database; BAF is bioaccumulation factor; WEAP is Wildlife Effects Assessment Program.

- When calculating the exposure estimate for a receptor, the available data are presented to the user for selection.
- By default, parameters are automatically chosen to calculate the maximum and most conservative exposure.
- The user to decide must decide what level of conservatism in these parameters will be selected.
- Each internal parameter value is referenced, and the references accompany the exposure estimate and are exportable.
- TWEM1 also allows users to enter their own parameter to calculate the most site-specific values. User-input values with site-specific data may provide the most reliable exposure estimates.
- Output from this model module will be available for input into other ARAMS modules via FRAMES 2.0 (Figure 1). The modeling framework will also be flexible to allow for modification of the exposure model to include dermal and inhalation exposure as additional methods become available.

TWEM1 is a project-oriented analysis tool

Menu Items: The function of TWEM1 is controlled using the major menu items and toolbars.

Project View: Displays the project in a hierarchical view.



Quick View and Edit: Displays a quick view of the TWEM1 objects and their properties.

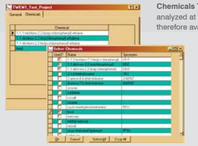
System Libraries: Contains property information related to the various elements of the TWEM1 application.

TWEM Main Form

General Tab: Enter general information about the project.

TWEM is easy to use.

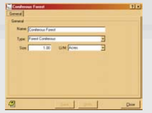
Project Edit Form



Chemicals Tab: The chemicals analyzed at the project site, and therefore available for analysis.

Upon selecting of chemicals and clicking OK, a list of the selected chemicals for the project is returned.

Habitat Edit Form

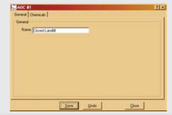


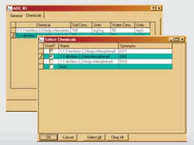
General Tab: Enter general information about the habitat.

TWEM exposure estimates and biota concentrations can be incorporated into all levels of risk assessment as evidence in risk determination but should not used unless they are completely understood.

Area of Concern Edit Form

General Tab: Enter general information about the Area of Concern.



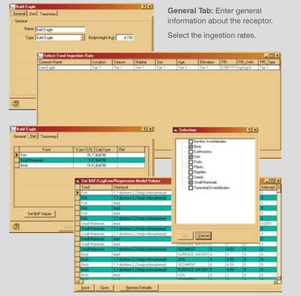


Chemicals Tab: Identify the chemicals in an AOC and enter or edit chemical concentration data associated with that AOC.

Habitat Wizard

Habitat Wizard: Allows rapid addition of multiple habitats to an AOC.

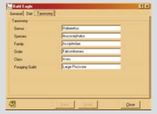
Receptor Edit Form



General Tab: Enter general information about the receptor.

Select the ingestion rates.

Diet Tab: Define the receptor diet, both the composition (i.e., food groups and/or food items) and the percent of total, and the BAF regression model to use. The receptor's diet is initially set by default when creating the new Receptor.

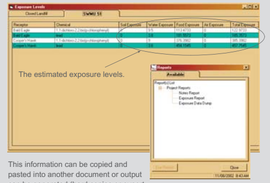


Taxonomy tab: Lists the taxonomy of the receptor

A Receptor Wizard is also available for rapid addition of multiple Receptors to a Habitat.

Output

Each tab represents a different AOC.



This information can be copied and pasted into another document or output can be generated (hard copies or export to Excel) using the Reports feature.

TWEM 1.1 runs on Microsoft®Windows®